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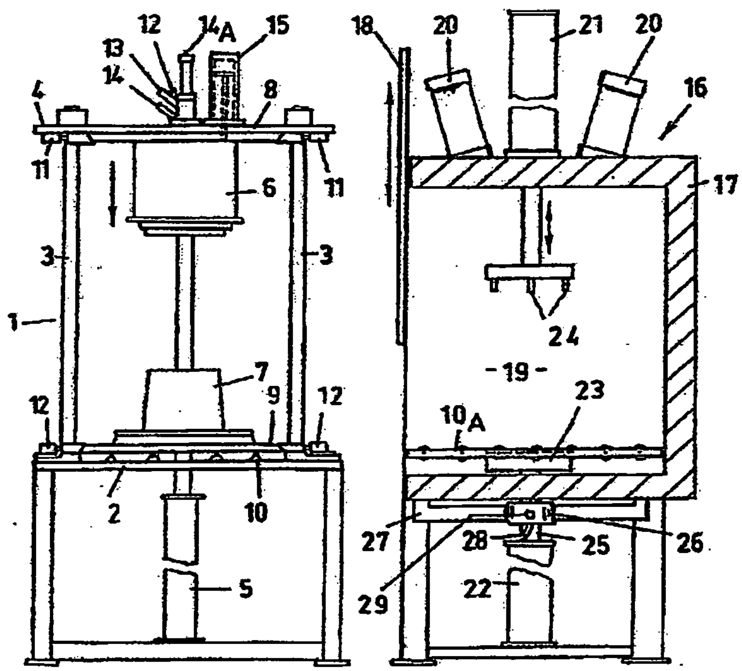
(54) Title: METHOD AND APPARATUS FOR MANUFACTURING ARTICLES FROM EXPANDIBLE THERMO-PLASTIC MATERIALS



(57) Abstract

A method of manufacturing an article by providing a micro-wave transparent openable mould with a cavity the shape of the article to be formed, loading the mould cavity with a predetermined quantity of pellets of plastics material which is micro-wave transparent and will expand when heated to fill the mould cavity and will bond together, surface coating the pellets with a substance to generate gas when heated, exposing the mould to micro-wave radiation sufficient to gasify the pellet coating to create heat and pressure in the mould cavity to expand the pellets to fill the cavity and bond the pellets together, followed by cooling the article and removing it from the mould cavity.

METHOD AND APPARATUS FOR MANUFACTURING ARTICLES FROM EXPANDIBLE THERMO-PLASTIC MATERIALS.

This invention is concerned with the formation of articles from expandible thermo-plastic material, for example polystyrene pellets.

It is well known that pellets of polymerised styrene or styrene and acrylonitrate when heated will expand due to the inclusions therein of volatile hydrocarbons. Heat induced expansion of a quantity of such pellets within a mould cavity which is smaller than the free expansion volume of the pellets will result in the pellets bonding to each other due to the partial melt of the bead surfaces as a result of the heat applied and the pressure developed in the cavity as the bead mass tries to expand beyond the cavity volume. The result is a coherent cellular mass having the external shape of the mould cavity. It is possible to form intricately shaped articles by this method.

The presently accepted process for the formation of articles by the above process involves exposing the pellets within a mould cavity to steam to provide the heat required for expansion/bonding. The steam is injected into the mould cavity through perforations in the mould walls. After the expansion/bonding step the mould is cooled with water.

As will be understood the mould is therefore subjected to rapid and dramatic fluctuations in temperature, 130 degrees Celsius during a heating step being commonplace followed by shock cooling. It is presently the practice to make the mould from metal and the working life of such

moulds is short due to the severe working conditions. The design of moulds is complex to provide for heating and cooling mediums and the introduction of the plastic pellets and the removal of the finished product. The provision of the foregoing in metal moulds contributes substantially to the cost of the mould. With the above moulding method there is also a need for ancillary equipment such as steam generation equipment and pipe work for delivering steam and cooling water to a number of locations in the mould. The foregoing and other manufacturing requirements, such as the need to provide non-uniform internal texture in the finished foamed product due to localised heating effects render the presently moulding techniques capable of improvement.

Other forms of heating, e.g. dielectric heating and the use of high frequency electric fields have been tried with limited success in order to overcome some of the above problems.

The prime object of the invention is to provide a method and apparatus for mould manufacturing articles from heat expandible polymerised plastic material which method and apparatus are simpler and more efficient than presently known methods and apparatus. It is envisaged that with the method and apparatus provided by this invention the mould will be made of a plastics material and accordingly the cost of a mould for an article can be dramatically reduced compared to the cost of making the mould for the same article from metal. The result will be a substantial reduction in the production cost per article. The invention

also provides a simple and effective way of producing an article comprised of a multitude of pellets fused together with a smooth substantially continuous exterior and with a substantially uniform internal texture.

Broadly, the invention can be said to comprise a method of mould manufacturing an article from a plastics material, said method comprising the steps of:

(a) providing a mould which is at least partially micro-wave transparent and includes a mould cavity the shape of the article to be formed and is openable to remove said article,

(b) loading the mould cavity with a predetermined quantity of pellets of plastics material which:

(i) are at least partially micro-wave transparent and

(ii) will expand when heated and

(iii) will bond together when heated to form an integrated mass of expanded pellets and

(iv) are each substantially completely surface coated with a substance which will generate gas when heated,

(c) exposing the mould to micro-wave radiation sufficient to gasify said coating substance and generate heat throughout said quantity of plastics material sufficient to cause said material to expand and occupy said mould cavity and said pellets to bond together and

(d) cooling the article in said mould and

(e) opening said mould and removing said article.

The invention further provides apparatus for carrying out the above method, said apparatus comprising

a mould handling station and a radiation chamber, said mould handling station including means to separate mould parts to permit the removal of an article form a cavity in the mould, means to charge pellets of plastic material into the cavity of a closed mould and transfer means whereby said mould can be transferred to the radiation chamber, said chamber having associated magnatrons to irradiate said chamber with micro-waves and having a chamber closure to substantially prevent micro-wave radiation leakage from the chamber, and mould clamping means activated during a moulding operation to retain said mould parts clamped together to resist the pressure generated within the mould cavity during an article forming sequence.

A presently preferred form of apparatus according to the invention will be first described with reference to the accompanying drawings in which:

Fig.1 is a is a schematic sectional elevation of the apparatus and

Fig.2 is a fragmentary schematic elevation of an alternate arrangement for providing movement of the mould within the radiation chamber of the apparatus.

The presently preferred form of the apparatus for carrying out the method is as illustrated in the drawings, it is however to be understood that the apparatus now described is representative of apparatus for carrying out the method of the invention and is not to be considered as the only apparatus capable for carrying out the method.

As illustrated the apparatus comprises a mould

handling station 1 having a bottom platen 2 with four support shafts 3 upstanding therefrom and a top platen 4 slidably mounted on the shafts 3. The top platen 4 is raised and lowered relative to the bottom platen 2 by a pair of side mounted piston in cylinder combinations 5.

The top and bottom mould parts 6 and 7 are respectively fixed to backing plates 8 and 9 and the backing plate 9 is supported on the bottom platen 2 through conveyor means 10 of known suitable type, in this example rotatable balls mounted in housings fixed to the bottom platen 2. There are readily releasable clamping means, indicated generally 11 and 12, on the top and bottom platens 2 and 4 respectively to edge engage the backing plates 8 and 9, in this case slidable members with angled faces to engage with like angled faces on the backing plates 8 and 9 and moved by small hydraulic or pneumatic cylinders. In this way the mould parts are temporarily secured to the backing plates 8 and 9 allowing the mould parts 6 and 7 to be moved apart by the piston in cylinder combination 5.

Mounted on the top platen 4 and aligned with a hole through the backing plate 8 and the mould part 6 and communicating with the moulding cavity within the mould there is a material charging device indicated 11 whereby partially expanded polystyrene pellets (although raw material in pellet form without pre-expansion can be used if desired) can be introduced into the mould cavity entrained in air, or in a water slurry, which enters the device through connection point 12 with the material admitted

through the connection point 13. There is a further connection point indicated 14 or 14A to the device 10 through which water (or other material preconditioning additive, for example water) is introduced into the bead entraining air either during or after the mould filling sequence.

There is a number of piston in cylinder units 15 mounted on the top platen 4 (only one is shown in the drawing) with the piston rods aligned with holes in the backing plate 8 and in the mould part 6. The piston rods (or extensions thereof) act as ejection pins to strip an article from the mould part 6 after mould part separation.

Not shown are air discharge ports in the mould part 6 whereby the bead entraining air can escape from the moulding cavity during a bead charging operation. It is also envisaged that suction means can be coupled to at least some of these ports to create a negative pressure within the moulding cavity to draw off excess preconditioning additive and to assist in filling remote sections of the mould cavity.

Positioned closely adjacent the mould handling station 1 there is a micro-wave oven 16. The oven 16 comprises a housing 17 with a vertically openable door 18 (although a horizontally opening door can be used if desired) through which access to a chamber 19 is obtained and there are seals to prevent radiation leakage when the door is closed and the chamber 19 is irradiated with micro-wave energy. The micro-waves are generated by suitable arranged magnatrons 20 mounted on the housing 17.

multiple mags

The devices 20 are of a power designed to suit the requirements of the oven and in the present instance the chamber 19 has a cubic capacity of approximately 2 cubic meters and the micro-wave generators have a power of of 5 kW each.

A conveyor means 21 comprised of rows of freely rotating wheels with their upper edges in a plane horizontally aligned with that of the mould handling station allows the mould and the associated back plates to be manually or mechanically (automatically) transferred (after release by the clamping means at 11 and 12) into the chamber 19. Upper and lower piston in cylinder units identified 21 and 22 are provided with platens 23 to exert mould clamping pressure on the mould backing plates 8 and 9 when the mould is in the chamber 19. The upper platen 23 is provided with plug-like pins 24 to engage in and seal off the holes in the mould upper part 6 through which the bead filling device and stripper pins associated with the mould handling station pass. The lower platen is just below the tops of the wheels of the conveyor means 21.

The piston rod 25 of the units 22 passes through a bush 26 in a bridge or other like bush support 27 and the piston rod 25 has a pair of diametrically disposed small angle helical tracks 28 which extend along part of the length of the piston rod 25. There are two diametrically disposed track followers 29 in the bush 26. As will be understood with such an arrangement when the piston rod of the unit 22 is extended it will be caused to execute a part

rotation due to the engagement of the followers 29 in the tracks 28. The reason for this facility will be explained later.

In a moulding operation the mould parts 6,7 and the respective backing plates (all made of micro-wave transparent material) is positioned in the chamber 19 where is rests on the wheels of the conveyor unit 21. The cylinders 21,22 are pressurised in a manner such that the lower platen moves slightly to engage the underface of the backing plate 9 and the upper platen is lowered to engage the pins 24 in the appropriate holes in the backing plate 8 and the mould part 6. The pressure applied is such as to hold the mould parts firmly engaged so as to resist the internal pressure generated during the article forming operation.

The chamber door 18 is then closed and the power to the magnatrons is turned on for a period determined previously as that required for the moulding operation.

The pressurised supply of fluid to the units 21,22 is regulated in a balanced fashion through valving and pressure regulation means so that an increase in pressure in the fluid to the unit 22 will be accompanied by a reduction in pressure to the unit 21 whilst maintaining a clamping pressure on the mould sufficient to keep the mould parts 6 and 7 firmly together in a sealed manner. As a result the mould assembly 6,7,8 & 9 will move upward in the chamber and at the same time because of the helical tracks 28 and the followers 29 the mould assembly will be rotated through a

part of a revolution, preferably in the order of 190 degrees. A reversal of the pressure distribution to the units 21,22 will result in a lowering of the mould assembly and a contra part rotation of the mould assembly. In the arrangement described the vertical movement is about equal to the height of the mould cavity.

By moving the mould as described above through the microwave field there is an averaging effect for the radiation to which the mould is exposed and the influence of "hot" or "cold" spots in the field is minimised. As will be understood the wave patterns and energy fields resulting from microwave generators are not exactly predictable and this is particulaly so where the fields of several magnatrons intersect. As a consequence there can be areas of above average intensity (hot spots) and areas of below average intensity (cold spots) within a microwave energy field. The proposed linear and part rotational movement of the mould assembly averages out the intensity of the micro wave energy to which the mould assembly is subjected.

The equipment described above may be modified in ways to facilitate operation and examples of possible modifications have already been give. In a further modification, see Fig.2, the units 21 and 22 are tandem units with the piston rods connected by cross-heads 30 and the cross-heads are coupled to the platens 23 through shafts 31 mounted in bearings 32 in the cross-heads 30. The cross-head mounted shafts 31 will then rotate as the followers 29 move along the tracks 28 in the lower

cross-head associated shaft 31. The advantage of this arrangement is that the pistons in the cylinders 21 and 22 are not required to rotate during the up and down and part rotation of the mould as is the case with the arrangement described with reference to the accompanying drawing.

The moulding process (the forming of the article in the mould cavity) involves the flash generation of steam within the mould cavity by microwave heating of the water coating of the plastic pellets. The steam will be substantially uniformly generated simultaneously throughout the bead mass thereby avoiding the problem often encountered with the introduced steam method in which almost invariably some pellets were insufficiently heated with the result that there was improper bead expansion and/or lack of fusion bonding between adjacent pellets. The result of the present invention is a substantially uniform texture throughout the finished product.

The foregoing description has been concerned with the simple situation where the pellets of plastic (in a pre-conditioned part-expanded form) are coated with water. It is possible to modify the process to achieve desired results by pre-treatment of the pellets. By way of example only there can be a use additives such as a "wetting" agent to ensure the pellets are uniformly coated with water.

In variations of the method above disclosed finely divided metal or other powder can be used for the coating of the surface of the moulding chamber, with varying degrees of effectiveness, preferably the powder is selected from the

group comprising aluminium, iron, carbon or zinc. The metal powder acts as a barrier to heat loss from the mould and provides a hot "skin" for the moulding chamber which fuses the surface of the expanded material into a smooth substantially continuous surface. The provision of such a surface is commercially desirable for articles to be displayed, for example such a surface finish is required on some packaging materials.

In a variation of the method as set forth above the starting air pressure within the moulding chamber is increased to above atmospheric with the result that the vaporisation temperature of the water within the moulding chamber will increase. The pellets can then be raised to a higher temperature than would otherwise be possible before the water within the moulding chamber vaporises to generate pressure within the moulding chamber. The result is a superior product with greater rigidity than a product formed in an unpressurised moulding chamber.

It has been found that a similar result can be achieved with atmospheric starting pressure wihin the moulding chamber if an ionic solution is used for wetting the pellets. An example is a salt and water solution.

An alternate form of polystyrene pellet, which is at least micro-wave opaque, can be achieved by having a powder or other form of material with required micro-wave opacity dispersed throughout each bead. The micro-wave opaque material is preferably, but not limited to, carbon black. As another example, a metal powder could be used as an

alternative to carbon black or mixtures of powders and materials can be used to achieve the required qualities for the pellets. The manner of manufacture of pellets having the above inclusions is not a feature of this invention. The pellets may or may not be surface coated as hereinbefore described.

The apparatus as hereinbefore described can include mould cavity temperature monitoring means. The temperature of the mould cavity is allowed to build up to a required limit at which it is maintained by cooling means. It would also be within the scope of this modification to provide the plastics material from which the mould is manufactured with fillers which would permit the mould to develop predetermined heat levels during the radiation stage. Temperature boosting means can be provided, if required, to bring the mould up to a required temperature.

The arrangement described utilising a mould filling and article stripping station separate from the heating chamber is that conventional materials such as non-transparent metals, plastics, rubbers etc. may be used to facilitate these operations. In addition where a plurality of moulds are involved this feature allows a faster moulding cycle as the operations of filling, post mould cooling and ejection can be occurring at the same time with the different moulds whilst there is a mould in the heating chamber.

Whilst the apparatus described discloses a single pellet filling head it is to be understood that more than

one pellet filling head may be provided for charging the mould cavity with pellets. Likewise, the references herein to a single cavity mould are not to be considered limited as multi-cavity moulds may be used in the performance of the invention.

The described arrangement may be modified if required to provide for the oven to be moved relative to the mould by suitable mechanisms which provide for the minimisation of effect of radiation field hot and cold spots, as described above.

A feature of the proposed method is the possibility of providing the mould with a lining of pervious material (such as woven fabric) or non-pervious material (such as PVC sheet) so that when the article is moulded the mould lining material will provide an outer surface covering for the article. In this way various surface finishes for the article can be readily obtained, a manufacturing possibility substantially impossible with the known form of steam heating of moulds.

The moulding material herein described has been polystyrene but it is to be understood that other materials may be used, for example, polyethylene and co-polymers of polystyrene and polyethylene.

I CLAIM:

1. A method of mould manufacturing an article from a plastics material, said method comprising the steps of:

(a) providing a mould which is at least partially micro-wave transparent and includes a mould cavity the shape of the article to be formed and is openable to remove said article,

(b) loading the mould cavity with a predetermined quantity of pellets of plastics material which:

(i) are at least partially micro-wave transparent and

(ii) will expand when heated and

(iii) will bond together when heated to form an integrated mass of expanded pellets and

(iv) are each substantially completely surface coated with a substance which will generate gas when heated,

(c) exposing the mould to micro-wave radiation sufficient to gasify said coating substance and generate heat throughout said quantity of plastics material sufficient to cause said material to expand and occupy said mould cavity and said pellets to bond together and

(d) cooling the article in said mould and

(e) opening said mould and removing said article.

2. The method of claim 1 including the step of coating said pellets prior to loading said pellets into said mould.

3. The method of claim 1 or claim 2 including the step of coating the surface of the mould cavity with a coating which is not micro-wave transparent.

4. The method of anyone of claims 1 to 3 wherein the

coating for the pellets is selected from the group comprising water or water and a wetting agent mix.

5. The method of claim 3 or claim 4 when dependent on claim 1 or claim 2 where the cavity coating is selected from the group comprising a finely divided metal powder or a finely divided metal powder in a carrier medium or carbon.

6. The method of claim 5 wherein the metal powder is selected from the group comprising aluminium, iron and zinc.

7. The method of anyone of claims 1 to 6 including the step of moving the mould within the field of the micro-wave radiation during at least some of the time during which it is exposed to the micro-wave radiation.

8. The method of claim 7 where the mould movement includes both linear and at least part-rotational motion.

9. The method of anyone of claims 1 to 8 including the step of increasing the pressure within the mould cavity above atmospheric prior to exposing the mould to micro-wave radiation.

10. The method of anyone of claims 1 to 9 including the steps of monitoring the temperature of the mould cavity during the moulding operation and applying heating/cooling to maintain the temperature within the mould cavity within a predetermined range during the moulding operation.

11. Apparatus to carry out the method of anyone of claims 1 to 10 comprising a mould handling station and a radiation chamber, said mould handling station including means to separate mould parts to permit the removal of an article form a cavity in the mould, means to charge pellets of

plastic material into the cavity of a closed mould and transfer means whereby said mould can be transferred to the radiation chamber, said chamber having associated magnatrons to irradiate said chamber with micro-waves and having a chamber closure to substantially prevent micro-wave radiation leakage from the chamber, and mould clamping means activated during a moulding operation to retain said mould parts clamped together to resist the pressure generated within the mould cavity during an article forming sequence.

12. Apparatus as claimed in claim 11 including means for moving the mould within said chamber to impart linear motion to said mould and at least limited rotational motion to said mould.

13. Apparatus as claimed in anyone of claims 10 to 12 wherein the mould handling station includes a base provided with said transfer means and releasable clamping means to grip a first mould part, a movable platen provided with further releasable clamping means to grip the second mould part, and platen moving means to move the mould parts apart and together, said pellet charging means is mounted on said movable platen and communicates with an opening into the cavity of the mould, said pellet charging means including connections whereby pellet entraining fluid can be introduced into the mould cavity.

14. Apparatus as claimed in claim 13 including further connections on the pallet charging means to admit a further fluid material into the mould cavity with the pallets.

15. Apparatus as claimed in anyone of claims 11 to 14

including ejectors mounted on said movable platen and aligned with apertures in said second mould part which are movable into said apertures to eject a moulded article from said second mould part when separated from the first mould part.

16. Apparatus as claimed in claim 12 where the means to move the mould in said chamber includes an upper and a lower piston in cylinder arrangement with oppositely disposed pressure plates on piston rods of the respective pistons to engage the first and second mould parts and clamp them together, helical track and track follower arrangement connecting one of said piston rods to a stationary member whereby said one piston rod is caused to rotate when is is moved axially relative to said stationary member.

17. Apparatus as claimed in claim 16 wherein the upper and lower piston in cylinder arrangements are each comprised of two piston in cylinder units in tandem with the piston rods thereof connected by a cross-head, a rotatable power shaft with one of the pressure plates at one end is rotatably mounted in the cross-head with its axis parallel to the axes of the piston rods associated therewith, and said helical track and track follower arrangement connects one of the power shafts to said stationary member.

18. Apparatus as claimed in claim 16 or claim 17 including valving means whereby the pressure of operating fluid to the upper and lower piston in cylinder arrangements is maintained at a level to maintain the mould parts clamped together whilst a pressure imbalance between the upper and

lower piston in cylinder arrangements is provided to cause linear movement of the mould in the chamber.

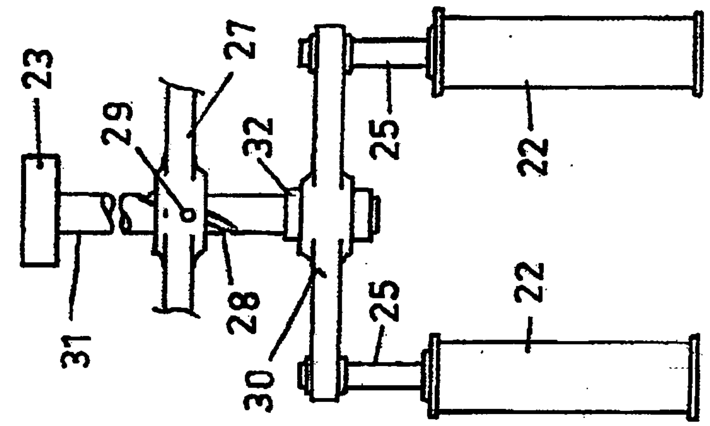


FIG. 2.

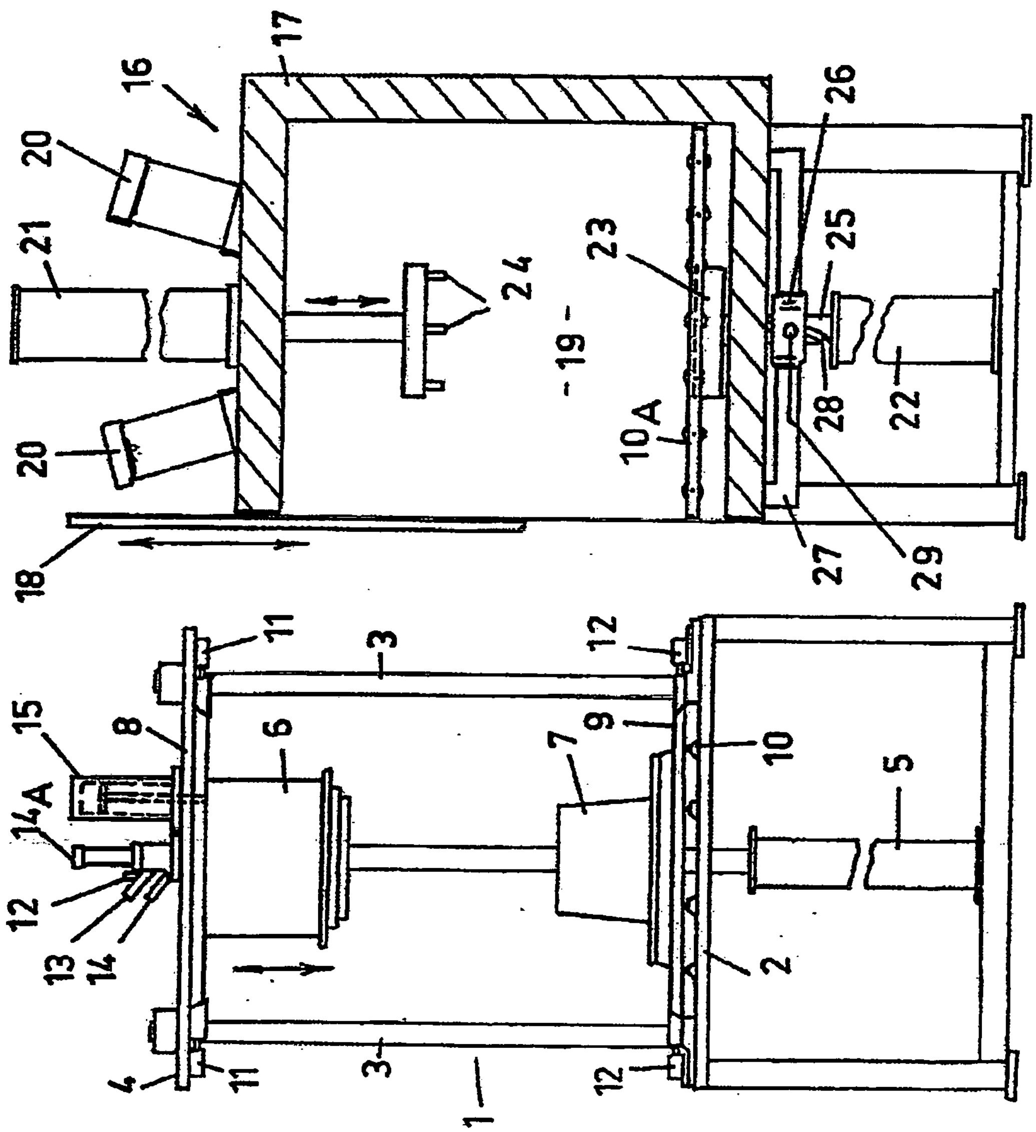


FIG. 1